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Author(s): Dickson, Peter
Rae, Philip John

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Low-voltage detonator response to electrostatic discharge

Peter Dickson & Philip Rae

M-6 Explosive Applications and Special Projects
Los Alamos National Laboratory

Introduction

Most explosives exhibit some level of sensitivity to electrostatic discharge[1]. Low-voltage detonators (a.k.a blasting caps) are commonly referred to as Low-Energy Electro-explosive Devices (LEEED), a category that may indicate elevated sensitivity to induced current and/or electrostatic discharge (ESD). These devices comprise a resistive bridge wire (~ 2 Ω) surrounded by a pyrotechnic or primary explosive such as lead styphnate, in contact with a primary explosive charge, typically dextrinated lead azide, followed by an output charge, generally PETN. The 50% firing current is typically around 1 A.

They are supplied with their leads twisted and shorted to prevent induced currents from heating the bridge wire, and are known to be somewhat vulnerable to such currents if the leads are separated. They are also often asserted to be sensitive to human-level ESD but, in fact, are engineered to be ESD safe.

Human-level ESD is generally represented by a capacitance of 100 pF and a voltage of up to 15 kV discharging through a 1 kΩ resistance[2,3]. Actual testing has demonstrated that a person can, under low-humidity conditions, be charged as high as 30 kV or so, after which corona discharge limits further charging.

This report describes tests performed to assess the ESD safety margin by subjecting the blasting caps most commonly-used at LANL to a range of ESD stimuli from human level to approximately 50 x human level.

Experimental Method

A high voltage discharge unit was designed to provide single-pulse discharges up to 40 kV at 100 pF, 1 nF, and 5 nF, as shown in figures 1 and 2.

The tests were conducted inside a standard 12 g-rated boom box, configured to produce a case-to-pin discharge that allows the discharge path to go through the explosive. This configuration results in prompt ignition when the discharge from a Tesla coil is applied. The arc jumped from a rounded (to reduce corona) 18-gauge wire loop to the end of the detonator case. After charging the system, a remotely controlled motorized stage moved the discharge loop towards the detonator until the circuit self-discharged. The trigger circuit was designed to limit the arc to a single event until the loop was backed off and recharged.

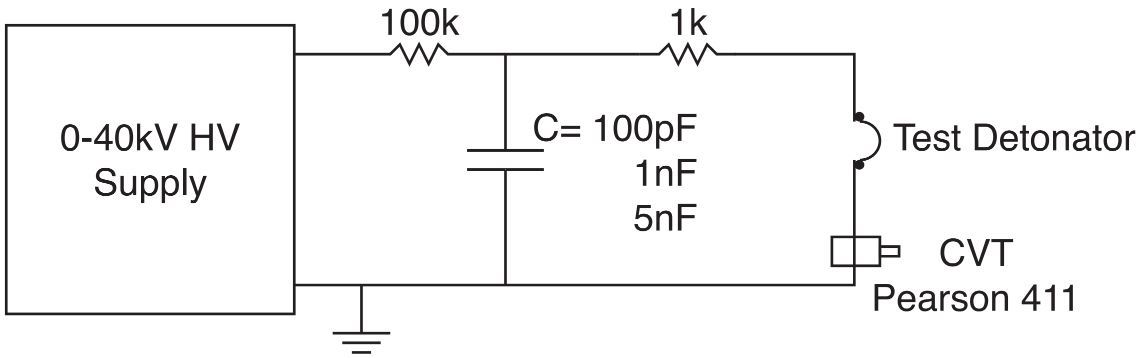

Figure 1. Test circuit schematic.

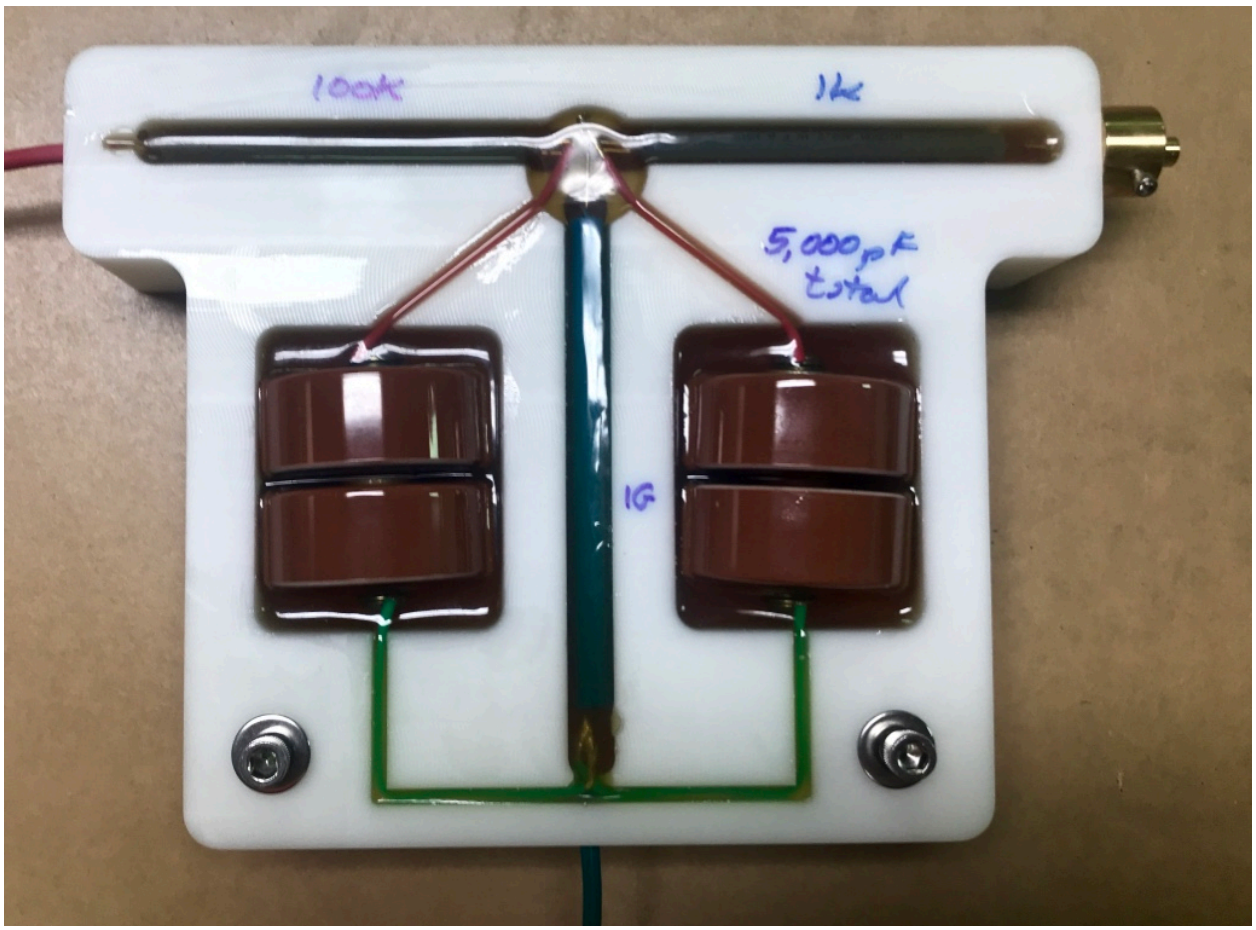

Figure 2. Image of the high-voltage test circuit.

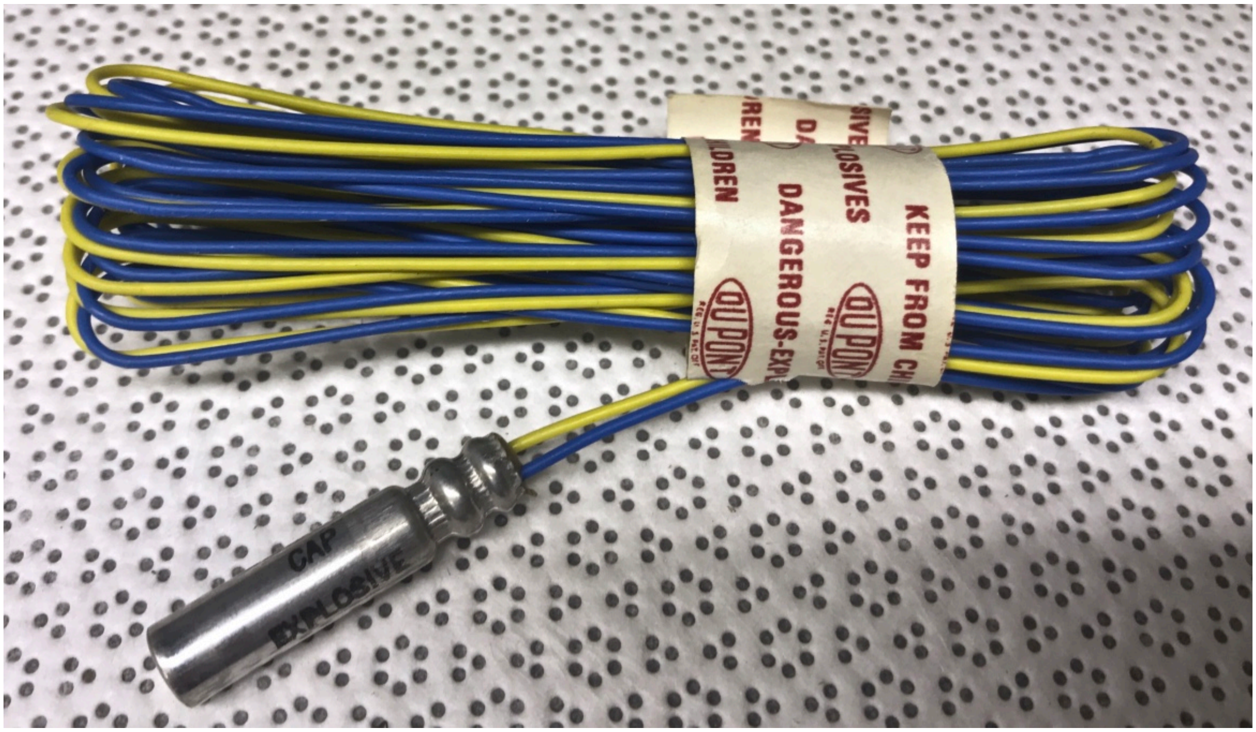

Figure 3. Dupont #8 blasting caps

The current flowing in the circuit was measured using a 411 current-sensing Pearson coil with a sensitivity of 0.05V/A, and recorded on a Tektronix scope at a sample rate of 5 Gs/s.

The blasting caps tested in this study were #8 detonators manufactured by Dupont, shown in figure 3.

Results

After some initial scoping to optimize the test it was determined that the maximum achievable, corona-limited voltage was 30 kV. A blasting cap was then subjected to 4 arcs at 30 kV, 5 nF, without any visible reaction. The resulting current trace is shown in figure 4. Since this is the maximum energy available with the test system, and approximately equal to 50 x the maximum recorded human ESD energy level, the lower capacitance tests were not conducted.

The blasting cap was then fired in design mode at 3 kV, 1 µF, and functioned normally.

Conclusions

A very conservative overtest of ESD with a low-voltage blasting cap produced no reaction on multiple discharges, suggesting that this is not a viable initiation mechanism. That is consistent with industry-standard practices (no ESD protection) and the lack of any documented cases of accidental initiation by static discharge.

This study only tested one model of #8 blasting cap, but the test equipment is available to test any low-voltage device as needed.

Note that blasting caps that include a delay fuse may be significantly more sensitive that the instantaneous variety commonly used at LANL[4].

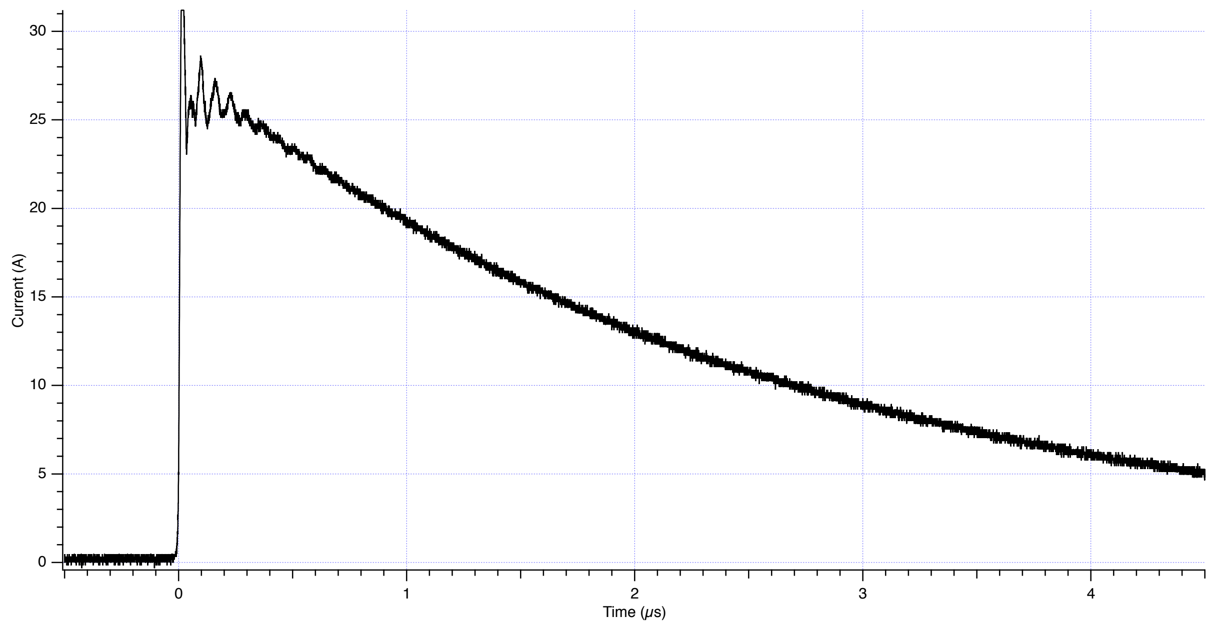

Figure 4. Current trace for 30 kV, 5 nF.

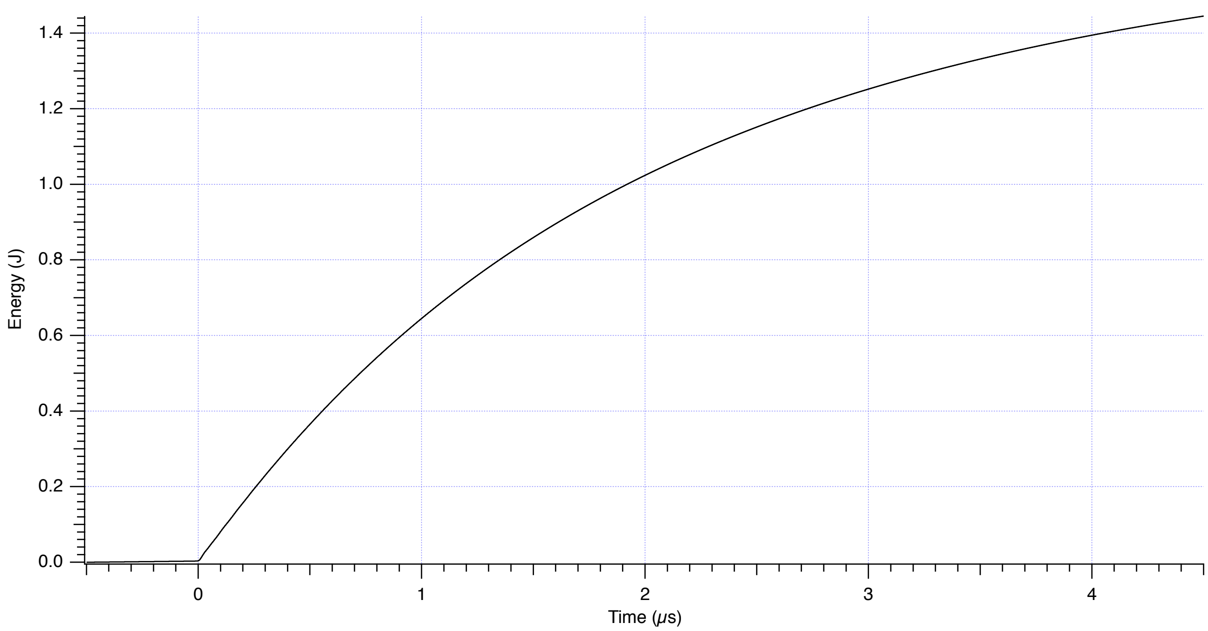

Figure 5. Energy deposition, 30 kV, 5 nF.

References

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